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Chapter 13

German Rockets in Africa: The Explosive Heritage of Peenemünde*

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Overview

This historical paper reviews the technical development and the political impact of two "intelligence affairs" with German rocketry in African countries: (1) the Nasser missiles and space projects in Egypt during the 1960s, and (2) the private OTRAG venture in Zaïre and Libya during the 1970s.

On July 21, 1962 the world was made aware of a rocket development program in Egypt with the launches of two liquid missiles. One year later, Egypt disclosed its first 2-stage booster, named Al Ared (The Pioneer). It was announced that this rocket could be modified as a satellite launch vehicle, and that Egypt had plans to launch a first satellite in the 1964-1965 time frame.

On May 17, 1977, a small rocket, developed by the private German firm OTRAG first took off from a plateau in Shaba (Zaïre) to demonstrate the feasibility of a low-cost propulsion module. It was announced that a modular 3-stage booster for satellite transportation would be tested in late 1981 in Zaïre, but in late 1979, OTRAG had to leave Zaïre.

On March 1, 1981, the 4th OTRAG rocket was tested at a Central Sahara site in Libya, and this launch provoked strong criticism from the international community. A last launch of an OTRAG sounding rocket with a German payload was made from Esrange, Kiruna (Sweden) on September 19, 1983.

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This review will show some parallelism in the development and termination of these two rocketry projects (with some space ambitions) which have some connection to Peenemünde during the Third Reich such as:

1. The "propaganda" effect insisting on the use of space technology for scientific purposes (in Egypt) and for business activities (with OTRAG) was suspected to dissimulate military goals of rocketry development
2. The presence of German engineers in the development of Egyptian missiles and of OTRAG modular rockets established a relationship with people who worked in the development of German V-2 rockets in Peenemünde during the Second World War.
3. The failure of the two rocketry ventures found an explanation in the facts that technically, the two ventures were designed on bad principles because the Egyptian as well as OTRAG rockets were too heavy and they had no accurate guidance system; and politically, the activities of rocketry in Egypt (severe reaction from Israel), in Zaïre (critics from the USSR and Angola) and in Libya (disapproval of the USA, Israel and European countries) provoked heavy pressures on Germany to stop these projects of rocket development outside its territory.

Part 1: Rockets and Satellite(s) of Nasser: Prestige or Bluff?

On July 26, 1952, Colonel Gamal Abdel Nasser (1918-1970) successfully achieved a coup d'Etat against the Royal authorities of Egypt. This country, along the Nile Delta and the Suez Canal, was in the situation of great poverty. Starting a socialist regime based upon neutralism and pan-Arabism, President Nasser became one of the influential leaders of the neutral non-aligned countries in the world. Reinforcing his power in Egypt, he became "the Rais" with a regime of unique parts. Looking for money to build the Dam of Aswan on the Nile, he expropriated the French-British Suez Canal, provoking the military reaction of France and of the United Kingdom; this led to the second Israeli-Arab war in October 1956.

Egypt lost this 1956 war. As an international ally, it turned to the USSR for its industrial development and for the construction of the Aswan Dam. Giving priority to the unity of the Arab countries against Israel and the Western world, Nasser established with Syria the United Arab Republic (UAR). In the early 1960s, he decided to nationalize the economic resources in Egypt. He encouraged nationalist prestige with some ambitious projects to achieve autonomy for Egypt in high-tech activities. The regime of Nasser started the development of an aerospace industry, with "secret factories" near Helwan and at Heliopolis. Egypt needed foreign technological assistance for its technological ambitions. In 1958, its intelligence services were particularly active throughout the Western

countries to collect information about the development of aircraft and missiles and to contact foreign specialists by offering them attractive conditions of life.

The cooperation with Moscow appeared to be difficult because of secrecy constraints for the transfer of Soviet technology. Cairo preferred to welcome with a lot of money German engineers and technicians: most of them were pioneers in rocketry and aircraft development before and during the Third Reich (Rolf Engel and Eugen Sänger for rocket systems, Willy Messerschmitt for reaction aircraft). The Egyptian program in aerospace technology concerned mainly the design and development of:

- strategic missiles based upon the biliquid V-2 concept;
- a training aircraft He-200 and a supersonic fighter He-300 (Mach 2.2).

The aim of this program was to demonstrate the paramount role of Egypt in the Middle East. President Nasser wished to reinforce its position as the leader of the "neutralist bloc", and to impress the newly independent nations in Central Africa. Through the autonomous development of military technology—against Israel—Egypt was grappling in a battle for superiority in terms of influence and prestige.

Liquid Rocketry in 1962-1963 with German Assistance

After 1960, some important industrial facilities sprung up from the desert, including the Helwan complex which was inaugurated by President Nasser in July 1962, to celebrate the 10th anniversary of the putsch; and the missile plant, named Factory 333, which was established at Heliopolis (located on the road from Heliopolis to Suez) in a restricted area, where President Nasser had his living quarters.

The rocketry program was under the management of Major General and Engineer Halouda, now retired. The Director of Factory 333, he was responsible for the tests and production of the missiles; he had to report directly to President Nasser. His assistant and second man was General Abu El-Azaiem. Considered as a highly qualified engineer who studied in Czechoslovakia and in Germany, he headed the engineering team consisting of German and Egyptian engineers; he was specifically in charge of the design and development of the liquid and solid rockets.

Egypt had to rely on Western know-how, especially from Europe, for the development of its aerospace infrastructure. Tooling for both the airframe and engine production lines were purchased from Western Europe. The intelligence services of Egypt were particularly active and efficient throughout the Western world in acquiring information about the new techniques in aerospace and to establish the right contacts with the qualified people in European countries. A lot of engineers from Germany—who worked previously at Peenemünde for the V-2 program and in the rocketry industry of France—came on the board on the

Nile. From the Institutes of Stuttgart and of Munich, German aerospace engineers and technicians came, in rotating teams, to Egypt for a period of two years, bringing new ideas in aerospace systems. At the same time, Egyptian engineers were trained and schooled by the Europeans in universities and technical institutions.

Among German people frequently quoted to be in Egypt, we found engineers employed by France at the ONERA (Office National d'Etudes et de Recherches Aerospatiales) in Châtillon, at the LRBA (Laboratoire de Recherches Balistiques and Aerodynamiques) in Vernon, and at the CIEES (Centre Interarmées d'Essais d'Engins Spéciaux) in the Sahara desert (Hammaguir launch site):

- Rolf Engel, who worked, after the Second World War, on French rocket systems. He was in Egypt with a team of German engineers, during 1951-1956, to build a rocketry factory and to develop a small rocket;
- Dr. Wolfgang Pilz, who was responsible for the propulsion and the wire guidance of the Véronique rocket. He came to Egypt during 1960 and returned to Germany in June 1965; his return appears to coincide with the end of the rocketry ambitions of Egypt;
- Dr. Paul Goercke, who contributed, as a specialist in electronics and guidance systems, to the development of the French Véronique liquid rocket;
- Dr. Hans Kleinwachter, who was an expert in electronics for rockets. He was murdered by agents – upon the request of the intelligence services of Israel – during the "fighting campaign" against the German engineers involved in the development of rocket systems in Egypt.

The role of the famous German engineer Eugen Sänger, who was the founder and professor of the Institut für Strahltriebwerke (propulsion engines), appears to be more enigmatic. He also came to Cairo, upon the invitation of the Egyptian authorities. Accompanying an Egyptian observer, he remained several months and was known as "the big expert." However, his son Hartmut E. Sänger downplays the participation of his father in the venture of the Egyptian rockets since his father stayed only two weeks in Egypt. Eugen Sänger did the same lessons at the University of Cairo that he did in his Institute in Stuttgart, but "after a few days he was told to come back by his superiors." Maybe he did not stay a long time in Egypt, and only in 1961, but he provided Egypt with rocket concepts and he sent a lot of German engineers from his Institute to Egypt. The group of engineers was nicknamed "Sänger Knaben" (which would be translated as "children of Sänger" or "altar boys!").

At Munich, Paul Goercke and Wolfgang Pilz established a company named INTRA GmbH to collect the patents for aerospace systems throughout Europe. The INTRA office was located at Schillerstrasse, in Munich; it cooperated with the intelligence services of Egypt. About the contribution of Peene-

münde engineers to French liquid rocketry, Jacques Villain stated in his paper entitled "France and Peenemünde" and presented in Washington, D.C.:

> "Creativeness was undeniably one of the strengths of these Germans... Note should be taken of the original concept of initial guidance by cable exemplified in Véronique, due to Dr. Pilz; the Aquitaine radar, the first French inertial guidance platform, built in 1958..."

So, the progress of Egypt in rocketry was spectacularly fast. This was mainly due to the efficient involvement of German engineers (with their know-how acquired at Peenemünde and in France) and to the enthusiastic participation of young Egyptian engineers and technicians.

During 1961 and the first half of 1962, the secret development of Egyptian rocketry was marked by static test firings and demonstration flights made in the desert. It was rumored (we did not receive an official confirmation) that 6 to 12 experimental rockets would have to have been fired for these tests to qualify their design as reliable and as operational.

On July 21, 1962, two small (Al Zafir) and two large (Al Kahir) single-stage rockets, with liquid engines, were launched in the desert some 80 km west of Cairo towards the south. President Nasser attended the four launches, which were described as successful. The public demonstration of Egyptian expertise in rocketry was celebrated as a great event in Egypt. An official picture showed President Nasser standing close to a rocket at the launch site. He stated that the first tests had been made successfully 14 months earlier and that the rockets were in quantity production.

Two days later, the "stars" of the military parade for the tenth anniversary of the Revolution were models of the rockets tested by Egypt. The exhibited rockets offered greater similarities to the French Véronique rocket than to the German V-2 missile.

The existence of Egyptian missiles able to reach targets in Israel and the demonstration of their efficiency surprised the intelligence services of Tel Aviv. The statement of President Nasser about a large number of rockets in the production phase and the provocative display of powerful rockets "made in Egypt" caused a serious reaction by the Israeli intelligence services. They started a discrete and efficient campaign "to hunt" everywhere in Germany and in Switzerland for the German agents who were suspected of helping Egypt with its aerospace projects.

On July 23, 1963, the mockup of a two-stage rocket (Al Ared) was shown during the military parade. Many rumors were circulating about the independent and imminent launch capacity of Egypt to put a satellite in orbit. Six Al Ared units were exhibited to celebrate Egyptian Revolution Day in July 1965.

A Small Scientific Satellite in 1964-1965?

The feeling of nationalism and the prestige of space were used by the Egyptian media to demonstrate the technological success of the Nasser regime. Behind the space activities of Egypt, Dr. Hassan Marie, Professor at the Eins-Shams University, was the Chairman of the Supreme Committee of Space Research. This Committee, consisting of 10 members and functioning as the recommendation body for the development of a Egyptian space program, discussed the program of scientific satellites to be launched by Egypt. Following information given by Dr. Hassan Marie to *Aviation Week & Space Technology*, the first satellite would be named "Star" and its payload would be oriented toward probing the Earth's electromagnetic field. An Egyptian observer, who was an engineering student and wishes to remain unidentified, released this statement:

- the first Egyptian satellite would be an Explorer-type spacecraft with its own propulsion unit made of solid propellant; the satellite itself would have a mass of 5 to 10 kg.
- the Al Ared launch vehicle, consisting of two liquid stages—a possible combination of Al Kahir and Al Zafir rockets—would carry as the third stage the satellite with its light payload. (See Table 1).

TABLE 1. THE THREE TYPES OF EGYPTIAN LIQUID ROCKETS, USING KEROSENE AND NITRIC ACID (+ INITIAL WIRE GUIDANCE), AS DESCRIBED BY THE MEDIAS OF EGYPT/UAR IN THE EARLY 1960'S

NAME (translation) type of launch platform	Configuration /Dimension	Payload/Range	First test flight
AL KAHIR **(The Conqueror)** fixed platform	Single-stage 12.5 m long 1.22 m diameter	1 t/600 km	in 1961-62
AL ZAFIR **(The Victory)** mobile platform	Single-stage 7 m long 0.9 m diameter	0.5 t /370 km	in 1962
AL ARED **(The Pioneer)** fixed platform	Two-stage 20 m long? 1.22 m diameter	1 t/950 km or 5-10 kg in low orbit [satellite with solid motor]	only on the drawing board (1st flight planned for 1964)

Because Egypt had a limited ability to track satellites, Dr. Hassan Marie recommended to the Minister of Scientific Research Dr. Salah Hedayet that the US should be invited to establish a satellite tracking station in the country. Some observers believed that the launch of the "Star" satellite would be delayed until adequate ground stations could be constructed.

A lot of various news circulated in the media about the development of rocketry in Egypt. *The London Sunday Times* and the *Washington Post* stated on 24 March 1963: "400 German scientists and technicians [are] said to be working on first Egyptian made rocket and nuclear warhead." One month later, on 23 April, *The Washington Daily News* stated about the United Arab Republic: "UAR announces plans to orbit a weather satellite this year." In May 1963, it was announced that an Al Kahir rocket was sent up to an altitude of 80 km with a meteorological payload. *Aviation Week*, in July 1964, reported about plans for a follow-on to the Star satellite: "The UAR's space projects are receiving good government support, Egypt officials contend, but with its small over-all budget, Egypt cannot undertake too many ambitious programs. Definitive details are not available on the Star satellite follow-on vehicle, but officials said it would be large enough to be considered in the scientific 'Space station' category."

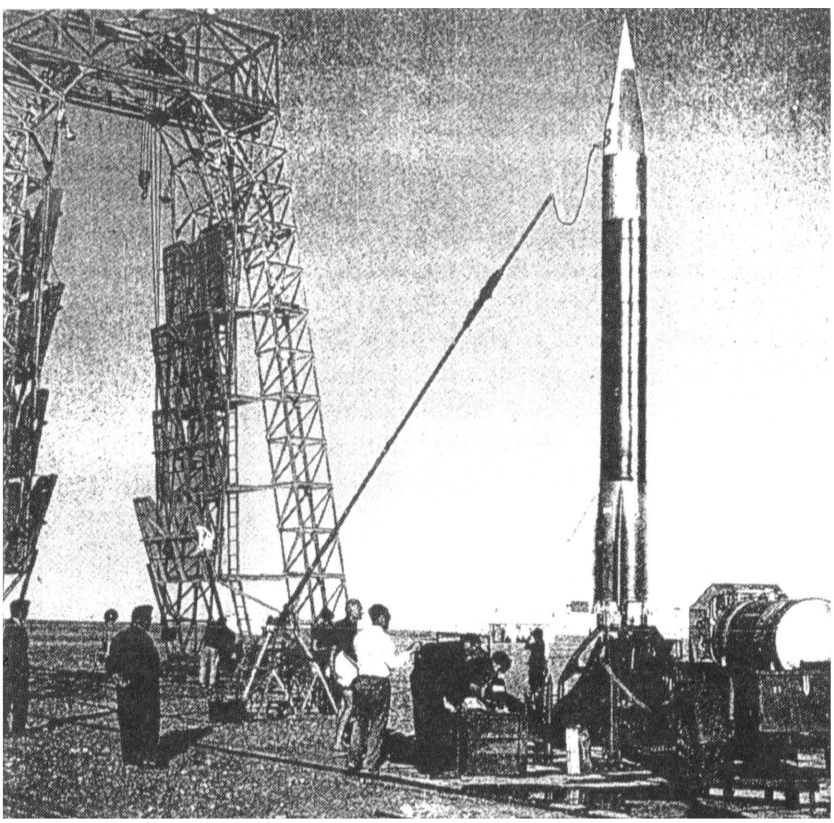
What was the true reality of a space program in Egypt? The Egyptian plan to launch satellites was really ambitious. At this time, only the USSR and the US were successful in putting spacecraft in orbit. France was preparing the Diamant vehicle—a derivative of the liquid Véronique rocket—to launch a small satellite [the first launch was made on 26 November 1965 with the Asterix capsule]. Our Egyptian observer—he got, as a young engineering student in the early 1960s, the chance to visit the Heliopolis rocket plan and to meet some Egyptian officials—stated: "From the government of Nasser, there was a large amount of misinformation. The rockets exhibited during the parade were wood mockups. The importance of German engineers was exaggerated and the production line was limited to tooling machines. The electronics systems were missing. Technically, the Egyptian rockets were perfect in terms of propulsion and aerodynamics. The rocket offered a great reliability but had no efficient guidance system and its structure was too heavy to achieve good performances. Flight accuracy and thrust/mass ratio were not very efficient." The project of Egypt/UAR to develop a satellite launcher remained on the drawing board, because of the Egyptian inability to solve the problems of in-flight guidance and to upgrade the accuracy in the performances of the rockets.

The Termination with the Israeli-Arab War of 1967

The participation of German engineers in the development of Egyptian weapons took on a serious diplomatic dimension when contacts were established by Egypt with German and Swiss industries to deliver guidance systems for up to 900 rockets (500 Al Zafir and 400 Al Kahir). Pressure was exerted by the US and Israel on the government of West Germany to stop the assistance of the German engineers and industries to the aerospace activities of Egypt. A majority of German engineers working in Egypt came back to Germany, convinced by a substantial offer from the federal authorities in Bonn. Finally, the liquid rockets of Nasser never became operational. They were replaced by Soviet Scud

missiles, which were more efficient. In June 1967, the third Israeli-Arab war came to a dramatic end for Egypt which lost the Sinai peninsula. It is reported that during this so-called Six-Day War, only two Egyptian missiles were fired against Israel: they missed their target by a distance of some 200 km. The problems of guidance were not yet solved. The defeat of Egypt in the Israeli-Arab War marked the end of the regime of Nasser and the termination of the dream of Egyptian engineers and scientists for the realm of space.

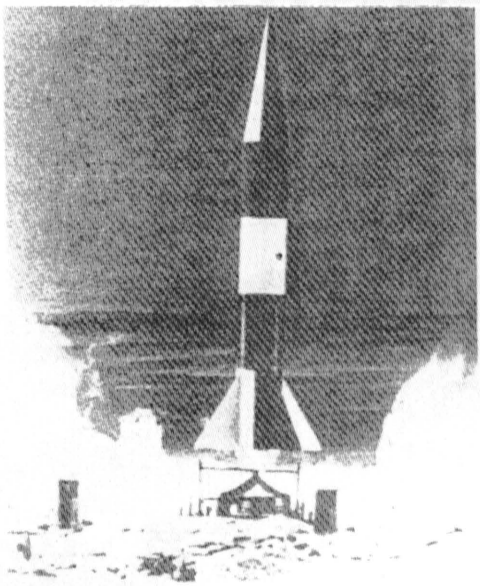
Nowadays, Egyptian engineers and scientists who were involved with the development of rockets and satellites in the 1960s, are retired. They will see an Egyptian satellite in orbit, as during the 1990s, Egypt will have its first spacecraft in orbit! Nilesat, a high-power broadcasting satellite, is currently being manufactured by the French-British firm Matra Marconi Space, using a Eurostar 2000 platform, and will be launched by an Ariane 4 rocket in late 1997. This launch will take place some 35 years after Egypt had planned the pharaonic project to put its own satellite into orbit using an indigenous rocket launched from its desert.

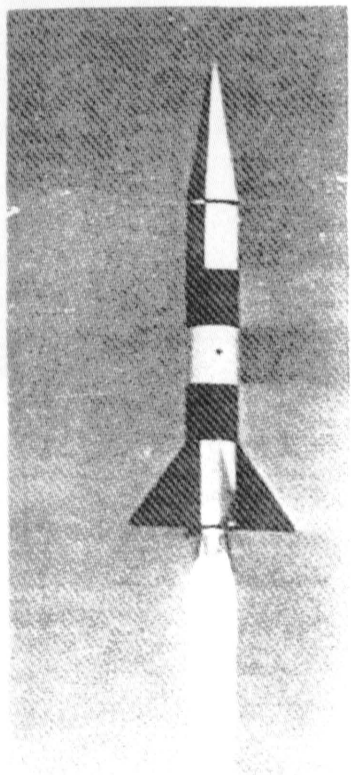


Some similarities between French and Egyptian Rockets, since German engineers participated in their development. Shown is the Véronique Rocket No. 18 in preparation at Hammaguir (Sahara) during February 1960 (Photo SEP).

ROCKETS OF NASSER: PRESTIGE OR BLUFF?

21 July 1962: launch of an Egyptian Al Kahir rocket "some 50 miles West of Cairo"



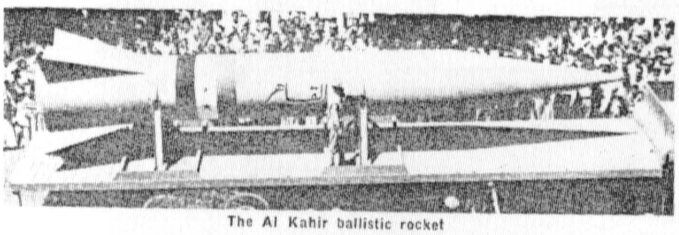


An Egyptian aerospace expert presenting the indigenous single and 2-stage rockets

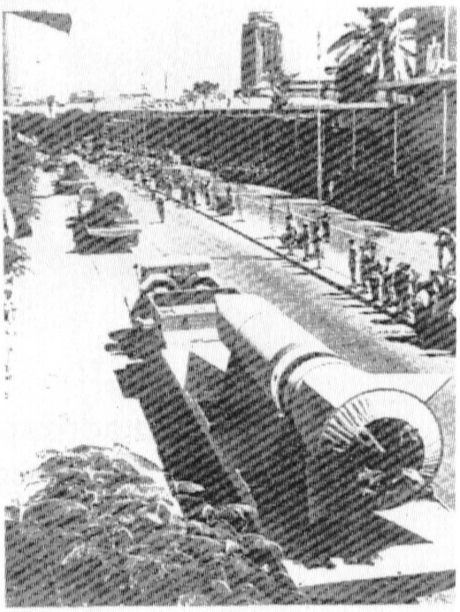
المتصم حسن شكرى .. أبعـاله عن الصواريخ استغرقت
خمس سنوات وهوايته الاساسية القراءة عن الفضاء . . .

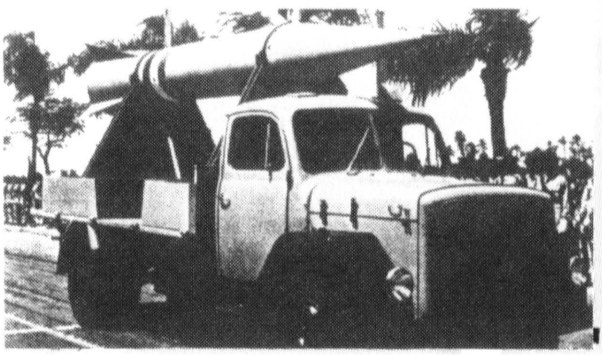
The Rais rocket show

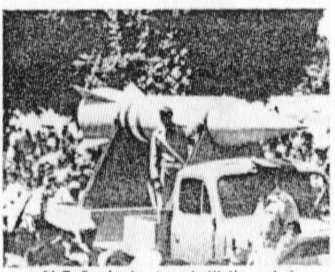
23 July 1962: Al Kahir and Al Zafir (single rockets)



The Al Kahir ballistic rocket





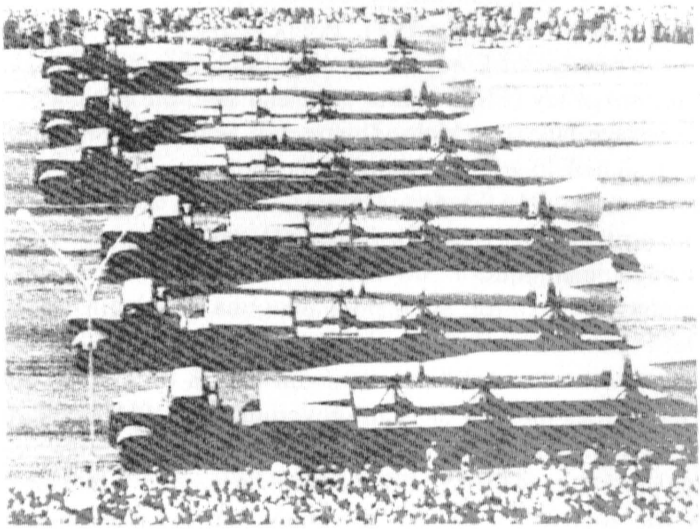


Al Zafir single-stage ballistic rocket

ROCKETS OF NASSER: PRESTIGE OR BLUFF?

TOWARDS SATELLITE LAUNCH CAPABILITY?

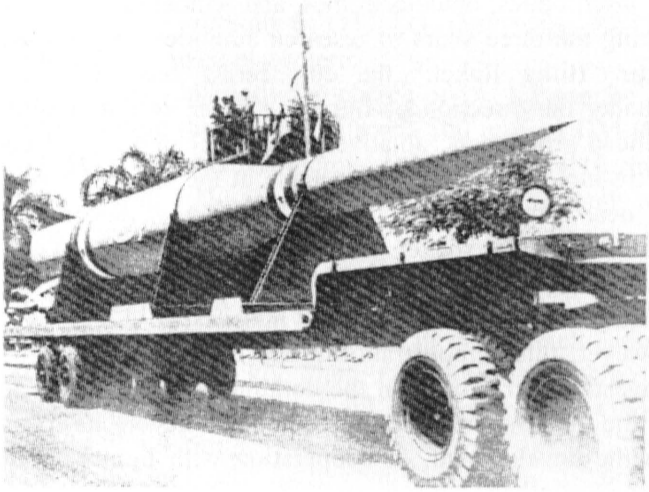
23 July 1963: El Ared (2-stage)



FLIGHT International, 8 August 1963

Named "Vanguard," Egyptian rockets of this type took part in the parade through Cairo marking the 11th anniversary of the Revolution on July 23. Said to have a range greater than that of any other Egyptian missile, it appears to be a two-stage version of the larger of two types of missile seen in the corresponding parade last year. Inspection of the weapon shows it is no closer to military use than were its predecessors

Flight International 1 August 1963



Part 2: The Strange Business of the OTRAG Modular "Volksraketen" for Low Cost Access to Space?

From the desert between the Nile and the Suez Canal, let's move 10 years later to the center of Africa, inside the equatorial forest of Zaïre. Launch operations with a new type of rocket, developed by a privately-funded German company, gave rise to a strange story with other political contexts and impacts.

Europe was disappointed by the Europa 2 program after the dramatic launch failure of 5 November 1971. Political discussions led to the decision to stop the development of Europa 2. In July 1973, it was decided to form the European Space Agency (ESA) and to go ahead with the French concept of a conventional 3-stage launch vehicle. This rocket, which later would be named Ariane, was designed to use well-known technology with the Viking engines on the first two stages. NASA and American industry were giving priority to the development of the Space Shuttle, with a reusable orbiting craft employing advanced cryogenic engines.

Germany looked for alternate methods for low-cost transportation into space. Between 1972 and 1974, a feasibility study for such a cost-optimized launch vehicle was funded for an amount of 1.8 million dollars by the West German authorities through the semi-governmental DFVLR (German Aerospace Research Establishment). This study was made by a German private company, Technologieforschung GmbH (Technology Research Ltd.) of Stuttgart. This company was founded in 1970 by the young aerospace engineer Lutz T. Kayser (born in 1939), who financially got the support of the widow of Eugen Sänger (he died in 1970). During his studies at the Technical University of Stuttgart, L. Kayser showed a great interest in new propulsion systems and was the protege of the German rocket pioneer Eugen Sänger; he had useful contacts with Wolfgang Pilz after his return from Egypt to Germany. Technologieforschung GmbH was active in research on advanced technologies, such as propulsion, rocketry, laser, optics, optoelectronics, and remote sensing systems.

During the three years of research activities on the concept of a low-cost booster or "Billig Raket," the engineering team of Technologieforschung GmbH, under the direction of Lutz T. Kayser, tested simplified engines using current cheap propellants, ablatively cooled chambers and commercially available electro-motors. Many firings, made at the Lampoldshausen test facility of DFVLR, near Stuttgart, demonstrated a low-cost design philosophy for mass production of modular rockets or "Volksraketen." For Lutz T. Kayser, this philosophy could give birth to satellite launch vehicles 80% less expensive than the existing rockets derived from classical missiles!

However, this demonstration phase did not convince the federal authorities to invest further money in the continuation of "Volksraketen" technology. In 1974, the government of Bonn decided to devote its rocket research efforts solely to the development, in cooperation with France, of the new European

launch vehicle. At that time, the 35-year engineer Lutz T. Kayser was so confident about the viability of his low-cost approach that he looked for funding from private investors. On 17 October 1974, OTRAG (Orbital Transport- und Raketen-Aktiengesellschaft GmbH) was established with the starting capital of 1 million DM (some $500,000). The Board of Directors consisted of knowledgeable people: Dr. Kurt H. Debus, one of the "Peenemünder" engineers in the US and the former Director of the NASA Kennedy Space Center, elected as Chairman; Dr. Theo Peters, retired atomic-physicist at the University of Stuttgart (he was a friend of Wolfgang Pilz); Carl E. Press, a haulage contractor of Frankfurt; and Dr. Irene Sänger-Bredt, the widow of Eugen Sänger. Lutz T. Kayser was the General Manager; he was joined by Frank Wukasch, as Public Affairs Manager, and by Helmut Billen (in September 1976), as Assistant Manager.

The OTRAG venture of the mid-1970s represented the first attempt to develop privately a low-cost system for access to space. This first privately funded attempt in space transportation business was located with headquarters at Neu-Isenburg (near Frankfurt) and with a technical plant at Stuttgart. Later, during 1978, it moved to a modern facility at Garching, near Munich. The OTRAG story was marked by some 10 years of up and down activities, with political impacts, during three specific periods.

1974-1978: Sensation and Reaction (the Time of Zaïre)

Private support which came from 600 individual shareholders—shares were tax-deductible—provided OTRAG with a first investment of some 50 million DM ($26 million). The clue to what OTRAG could be up to might be found in the motive of the shareholders: doctors, lawyers and dentists, liberal professions—managers of entertainment enterprises, of publishing houses, of transportation companies...—were among the investors in the high-risk OTRAG venture. Their main interest, reported in *The Financial Times* (July 1978): for every loss of DM 1,000 they suffered in OTRAG, they were able to deduct 2,200 DM from taxable gains made elsewhere.

This tax deduction was apparently the choice of Dr. Kayser: he could anticipate little trouble in getting the amount of some 500 million DM ($250 million) to develop OTRAG rockets as commercial launch vehicles. During its first three years of activities, from 1974 to 1976, OTRAG went through more than 2,000 test firings on a stand rented from the DFVLR. At the same time, Lutz T. Kayser used the German media to describe OTRAG efforts for cheap access to space and to criticize the expensive approach of the European Ariane rocket financed by Germany. Even Dr. Debus participated in the "launch campaign" of OTRAG, stating in the popular weekly *Bunte* (18 November 1976): "Ich bin sicher, das die Deutsche Billigrakete fliegt" ["I am sure that the German low-cost rocket flies"].

While Egyptian rockets were derivatives of conventional rockets, identical to the German V-2 and the French Véronique, the launch vehicles developed by Orbital Transport- und Raketen Aktiengesellschaft GmbH were described as a (r)evolutionary space transportation system based upon the combination of low-cost, mass-produced propulsion modules. A small team of some 40 engineers and technicians worked to standardize the propulsion unit in the form of an "asparagus bundle" made of long cylindrical modules: these pipe-line tubes could be assembled with very simplified engines into "Volksraketen" of different sizes. Every propulsion module was a cluster of four tanks associated with four completely autonomous and differentially throttling engines. The simplicity of modular construction, use of mass-produced materials, commercial availability of components, cost, density and performance of the propellants were the key criteria in the cheap and flexible design of the OTRAG rockets. The mass of the 24 m long module would be 685 kg (dry) and 5,444 kg (at launch).

Each of the clustered four engines was able to develop a thrust of about 32 kN (some 3 tons); it consisted, in its individual and fully integrated assembly, of a cylindrical combustion chamber and cheap nozzle, with radial injector, conventional ball valves, small electromotors (automotive windshield-wiper motors) as valve actuators, and its own control electronics and battery power supply. OTRAG rockets would use white fuming nitric acid, as an oxidizer, and kerosene, as fuel (the propellants were available at a price of 600 DM per ton). For the launch, the tubular tanks were filled about 2/3, while compressed air occupied the remaining volume. The fully automated systems for fueling and checkout operations were transportable on standard airline pallets.

As the propellant flew out through the injector into the combustion chamber, the ignition was immediate, initiating liftoff. While the rocket was ascending, adiabatic expansion had to keep the pressure up inside the tank. OTRAG stated that its engine was "the only known motor that could operate in a feed pressure range between 30 and 10 bar without instability and could he throttled in thrust for guidance and control purposes." In flight, the OTRAG rocket achieved pitch and yaw control by differential thrust throttling of the engine. The gimballing technology was considered too complex and too expensive. The chosen solution was to incorporate a throttling capability in each engine. The ball valves, allowing fuel and oxidizer to pass from the tanks to the engines, could be moved by their actuating electro-motors to any of these three positions: full open, half-open or closed. An inertial platform and computers in the payload section sent coded signals to small processors connected to the actuator of each engine; these processors in turn throttled the engines on one side or another to control the flight attitude of the rocket.

OTRAG released brochures with color pictures, insisting on the advantages of its low-cost standardized technology:

- the modular design for a flexible launch vehicle; this avoids long propellant feed lines which sometimes caused serious vibration or POGO effects on a traditional rocket;
- the simplified liquid propellant rocket engine using ablatively cooled chamber with a coating of asbestos and phenolic plastic resin;
- the guidance by differential throttling of individual engines, with only the action of valves and without additional components;
- the adiabatic blow-down feed system, which works as a sprayer and can never fail as all mechanical or electrical components are excluded;
- the tank units made with mass produced pipe-line tubes of 3 m which are assembled at the launch site.

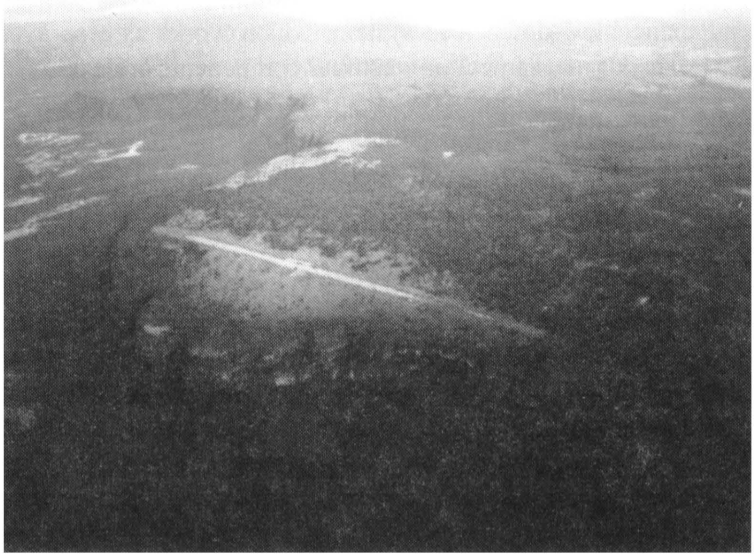
The Private "Cape Canaveral of Africa" Until the Year 2000

To launch its modular rockets, OTRAG had to find a site outside Germany. It looked for a range close to the equator, offering the advantage of velocity gain from the Earth's rotation. OTRAG officials talked to governmental representatives in equatorial countries: Brazil, Indonesia and Zaïre. Lutz Kayser explained in *Aviation Week & Space Technology*:

> "General Mobutu, President of Zaïre, was the fastest to react and to decide that he wanted the Cape Canaveral of Africa. Zaïre gets the prestige and will be paid for the rental of 100,000 km^2 of range, but payments are deferred until 1980, when we hope to start commercial launch services. We have a contract with Zaïre to the year 2000, but we don't really know how long we can stay there."

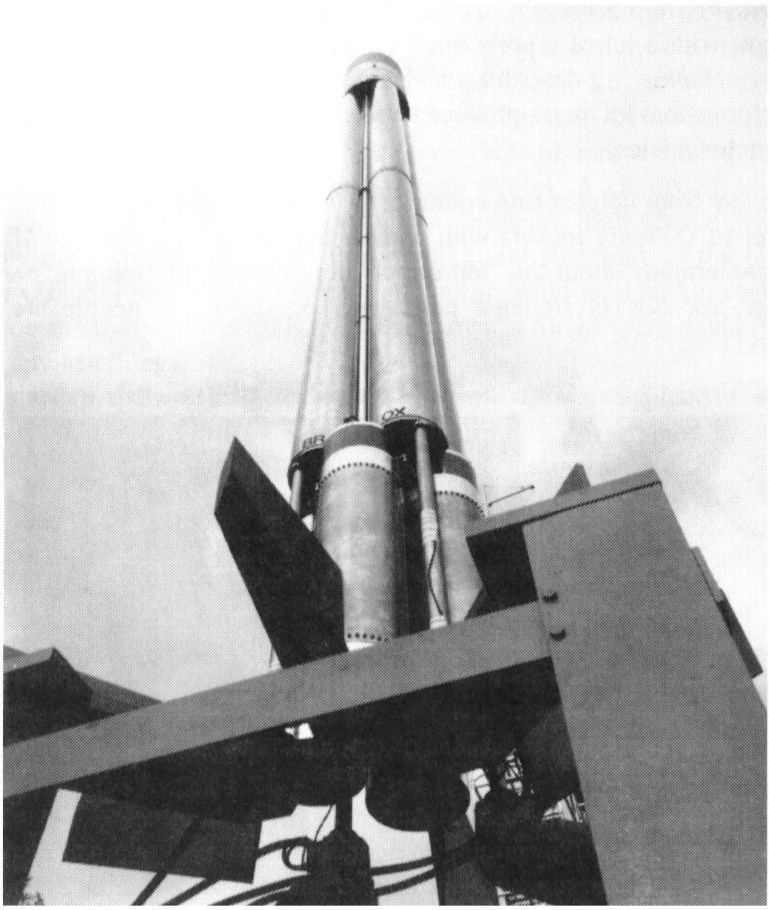
A first lease agreement was signed in Zaïre on December 6, 1975 between the private company OTRAG and the main authority (the Presidency) of the Republic of Zaïre. This agreement was confirmed on March 26, 1976. It concerned the exclusive right to use an area of 100,000 km^2, half the size of West-Germany. This territory, on the plateau of Shaba, was adjacent to Lake Tanganyka, on the borders of Tanzania, Zambia, and limited by the rivers of Zaïre and Lukuga; this huge plot was inhabited by some 10,000 Bushmen. Article V stated that OTRAG would pay an annual rental fee of 25 million Zaïre (which was equivalent, at the exchange rate of 1977, to $50 million). This payment had to be made on the last day of each year, starting the year that OTRAG would have a commercial launch with a rocket. After this first payment, some adjustments could be made after negotiations with the government of Zaïre. OTRAG promised to use its first operational launch vehicle for the launch of an experimental satellite for earth surveillance. It also offered a 20% discount on the cur-

rent price to launch a geostationary communications satellite for Zaïre. The right of OTRAG to operate freely in Shaba was valid until the end of the year 2000. The State of Zaïre was not allowed to abrogate this agreement for any reason before this date! This agreement was largely criticized by the African countries, describing it as a new act of colonization from a European company.



OTRAG built a 2.1 km long runway on a plateau of 1,300 m altitude in the north of Shaba Province (Zaïre).

At an altitude of 1,300 m, on a plateau which overlooks the river Luvua, OTRAG selected in the north of Shaba a site for a runway and a launch facility. Very rapidly, an infrastructure—roads, bridges, houses—grew up, using trucks, bulldozers and the materials of Stewering & Fils. This enterprise was presented as an OTRAG subsidiary which specialized in bridge construction in developing countries; it used its own method of modular concrete construction. In six months, on the rocky plateau, a 2,100 m x 40 m wide airstrip was built to welcome two aged but refurbished Argosy transport aircraft; these carriers were owned and operated by another OTRAG subsidiary, named OTRAS (OTRAG Range Air Service), to bring from Germany to Shaba the modular rockets and the associated ground equipment for checking, fueling and control operations. The impressive presence of OTRAG in Zaïre was observed from space by Soviet spy-satellites of the Cosmos program.



The first propulsion module tested by OTRAG on the test stand in Germany and in flight from the launch site in Zaïre.

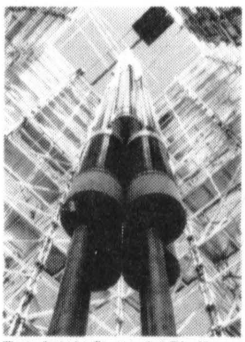
On May 17, 1977, at 10:15 local time, the first "Volksraket" of OTRAG was launched after quick preparation from a provisional launch infrastructure. It consisted of a 6 m long propulsion module with four tanks and four engines, developing a total thrust of 125 kN. The 9 m high OTRAG rocket completed a perfect and safe "first": though its tanks were filled to only 20% of their capacity, it soared without any hitch to an altitude of 10,000 m. This was the first German launch of a large rocket since the V-2 missiles of the Second World War! The announcement of this first OTRAG launch got worldwide media interest and had an impact in three different ways:

1. ***publicity*** pushing ahead the OTRAG venture in the business of attractive launch services, convincing new shareholders to put forth further money for commercial access to the new world of space;

2. ***curiosity*** from aerospace specialists and from science & technology magazines, with a lot of reports (*Aviation Week*, BIS *Spaceflight*, *Popular Science*, *Hobby* ...) describing and evaluating the original concept and real performances of mass-produced rockets to develop a family of modular launch vehicles;

3. ***anxiety*** from neighboring countries in Africa concerning the military character of OTRAG rockets with nuclear warheads, and from the USSR and East Germany about the "top secret" development of German "cruise missiles" for NATO strategic purposes (i.e., the white people are coming back!).

Die »Orgel-Rakete«: Wie Geschäftsleute mit ihr Geld scheffeln wollen



Testrakete im Startgerüst. Die dünnen Rohre unten gehören nicht dazu. Durch sie fließt Treibstoff in die Tanks.

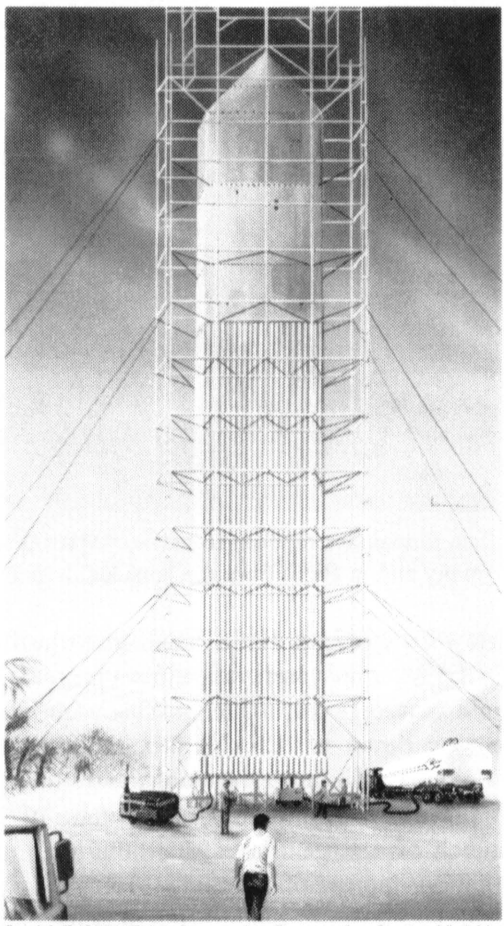
Zahlen beweisen eindrucksvoll, daß das Wort von der »Billigrakete« nicht bloß Propaganda ist.

Wie wird aus den 4800 Rohren eine Weltraumrakete? Erster Schritt: Man nimmt jeweils acht der Drei-Meter-Rohre und stellt sie übereinander. Ein Bajonettverschluß (er schnappt ein, wenn man eines der Rohre um wenige Zentimeter verdreht) hält die Teile zusammen.

Zweiter Schritt: Vier der so entstandenen, je 24 Meter langen »Spargel« werden Seite an Seite zu einem »Bündel« aneinandergeschraubt. An das untere Ende des Bündels werden vier Triebwerke montiert, und zwar zu den Rohren »versetzte«. Jedes Triebwerk muß ja mit einem Kerosin- und zusätzlich mit einem Salpetersäure-Tank verbunden werden. Die Triebwerke sind übrigens je einen Meter hoch, 27 Zentimeter breit und 60 Kilogramm schwer.

Sechshundert »Spargel« - und sechshundert Feuerstrahlen

Damit ist die »dritte Stufe« der Otrag-Rakete schon fertig. Sie soll der Nutzlast, dem Satelliten, im Weltraum den letzten »Schubs« geben. Die beiden übrigen Stufen werden auf die gleiche Weise zusammengebaut, bestehen aber aus viel mehr einzelnen »Spargeln«. Bei der größten Version bilden fünfhundert »Spargel« die erste Stufe – sie wird beim Start gezündet. Sobald sie leergebrannt sind, starten die 60 »Spargel« der zweiten



So wird die fertige Rakete kurz vor dem Start aussehen. Das Rohrbündel ist – mit Nutzlast – 40 Meter hoch und acht Meter dick. Die deutsche »Weltraum-Orgel« soll pro Start fünfmal weniger kosten als herkömmliche Raketen.

Spiegel 16

The German P.M. Popular technology magazine illustrated the OTRAG concept as the "organ-rocket," which operated with a low-cost infrastructure...

During the months after the "first" of OTRAG in Zaïre, the presence of Germany there with its rocketry systems, seemingly a new type of colonization in an African territory, was highlighted and criticized. Kayser's initiative was presented as the comeback of Germany in the business of military weapons; OTRAG was accused of building military bombardment vehicles for either West German neo-Nazis or for South African whites. A chorus of angry cries arose from the embassies of a dozen African countries; their screams were soon echoed by the Communist World. President Leonid Brezhnev of the USSR decried the OTRAG project as a German attempt to build up a rocket strike force. Regular observations of the OTRAG launch area in Shaba were made by Soviet Cosmos spy-satellites.

In the USA, the OTRAG affair caused an editorial dispute. In its March 1978 issue, the sex-entertainment magazine *Penthouse* published an exclusive report about West Germany's top secret nuclear missile: a very sensational and aggressive inquiry—4 pages written by Tad Szulc, a former *New York Times* diplomatic correspondent—stated that "in the heart of Africa's wasteland, West Germany is secretly testing the most deadly weapon of the nuclear age—the cruise missile V-3." Attacking this article, the California cultural magazine *Reason* reacted in July 1978 with the publication of "Rockets in Africa," a long corrective explanation by Robert Poole, Jr. with this heading: "A small German firm is launching rockets from Zaïre. The world-wide campaign to discredit it is a fraud. Why it was done reveals some bizarre realities of international power politics."

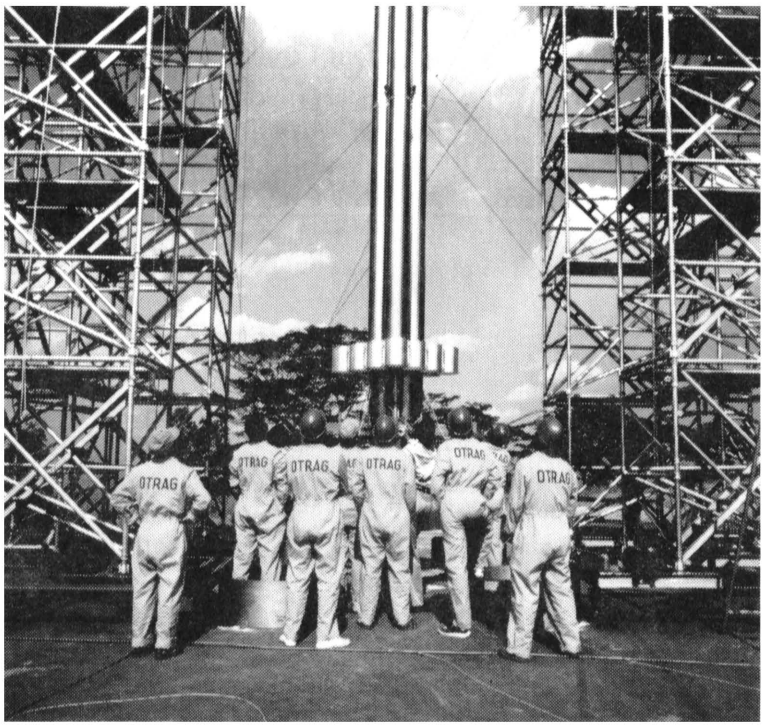
OTRAG officials continued to vehemently assert that the propulsion modules were developed and tested for space transportation purposes. They insisted on the facts that all of its launch vehicles would be assembled using the same tank and engine configuration, would offer an enormous bay for large payloads, and would compete directly with existing American rockets. A letter of Frank Wukasch on February 2, 1978, mentioned the very attractive prices (1976 value) of OTRAG services:

- OTRAG 2500 (Delta class) launch would be available for $7 million;
- OTRAG 5000 (Atlas-Centaur class) launch for $12 million;
- OTRAG 10000 (Titan III class) launch for $15 million.

One year passed before a new launch campaign was initiated by OTRAG in Zaïre. Why such a long interval? It seems that the transportation link between Germany and Shaba was not so easy with the old airplanes of ORAS. In the meantime, a more definitive and better equipped launch facility was built with mobile structures, a concrete platform, and steel pad. This second campaign occurred at a very bad moment, when the province of Shaba was suddenly invaded by mercenaries coming from Zambia and Angola. These "rebels" attacked the city of Kolwesi on May 12 and took Belgian and French people as

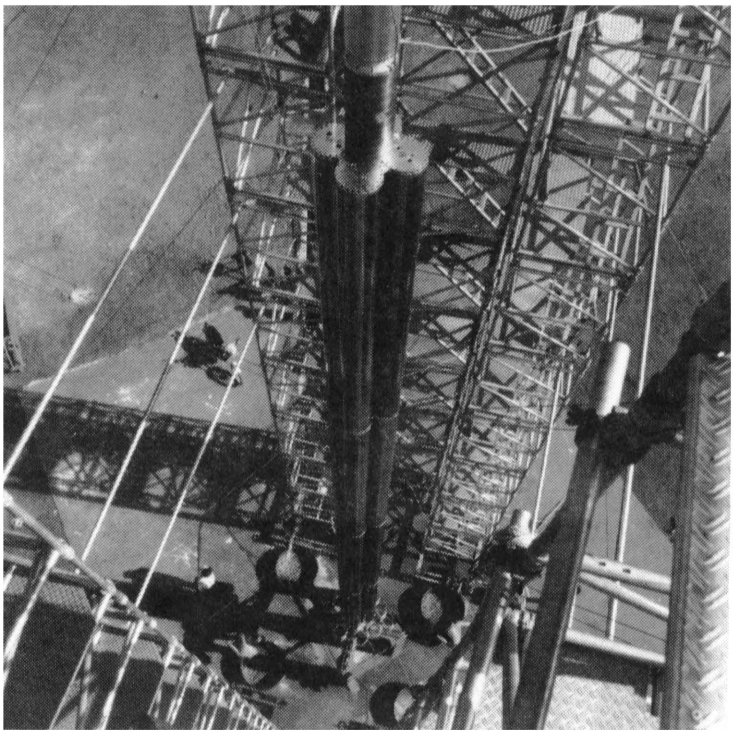
hostages... One week later, paratroopers from France and Belgium flew to Kolwesi to liberate them.

On May 20, 1978, the second OTRAG rocket, identical to the first one but with full tanks, was launched during the night; testing a guidance platform, it climbed to an altitude of some 30 km.

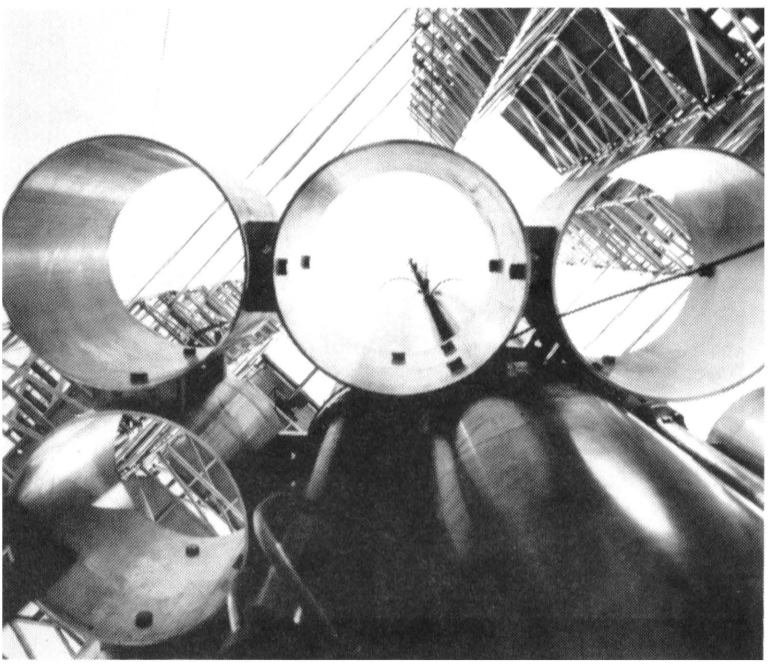


Preparation of the third OTRAG rocket (15 m high) which did not fly correctly on June 5, 1978.

On June 5, the third OTRAG rocket, using a 12 m long module with four tanks and engines, was ready to fly. In the OTRAG policy of openness, representatives of the Presidency and government of Zaïre, accompanied by the international media, were invited to attend the launch. President Mobutu Sese Seko came personally to the site of OTRAG in North Shaba and was welcomed by Lutz Kayser. However, the impressive test took on a dramatic dimension: while the rocket lifted off correctly, it turned rapidly because of the malfunction of a control valve and fell in the green valley of the Luvua river. Bad publicity: the OTRAG rocket functioned more as a cruise missile than as a space truck! This spectacular failure, described by OTRAG as a half success, is seen as the first demonstration of OTRAG's inability to enter the new market of space transportation services. Other facts contributing to the first fall of OTRAG can be identified:



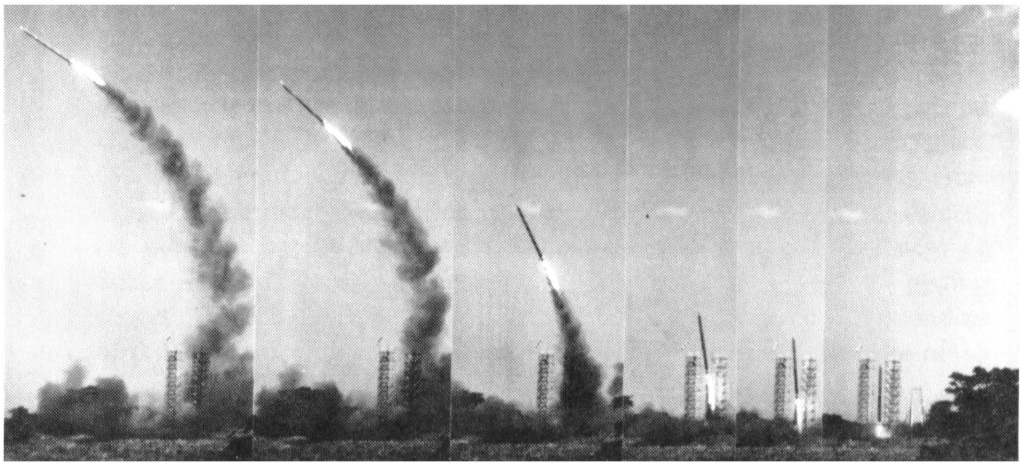
Preparation of the modular OTRAG rocket No. 3 (15 m high) which used aerodynamic stabilization, but did not fly correctly on June 5, 1978.



Simplified aerodynamic stabilization system for the modular OTRAG rocket No. 3, unsuccessfully tested on June 5, 1978.

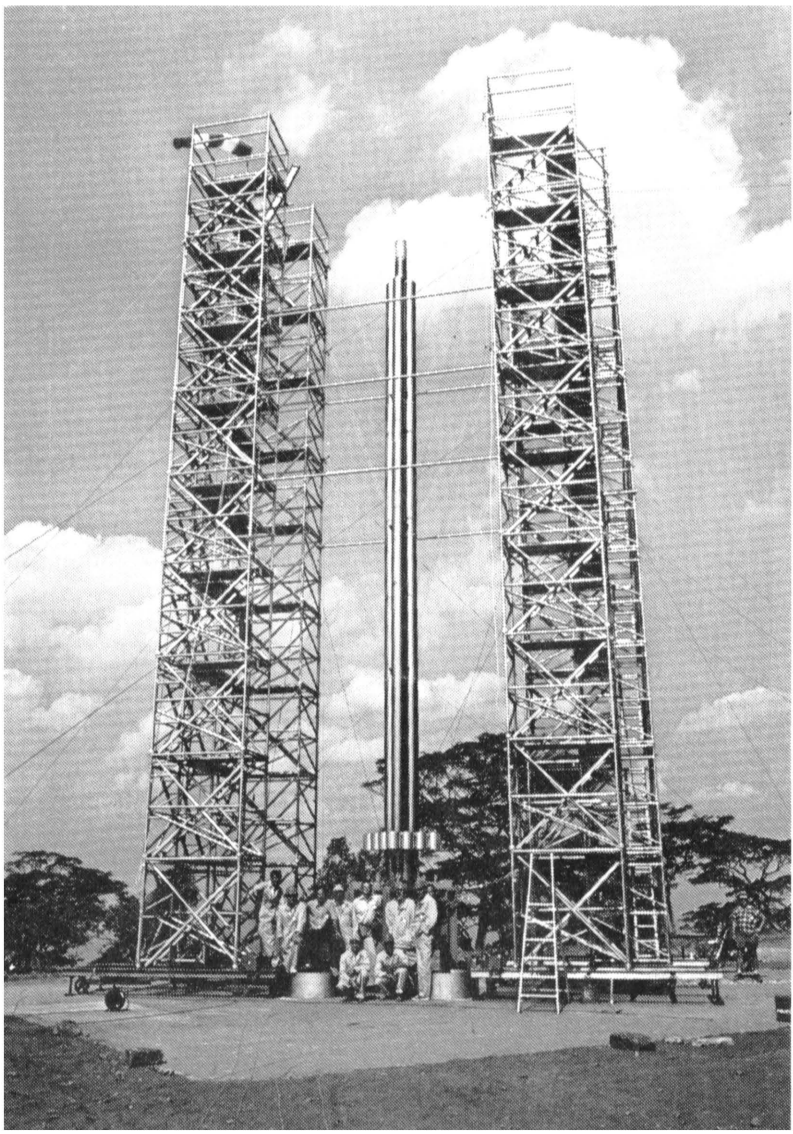
The simplified low-cost and easy-to-transport ground infrastructure on the launch site of OTRAG in the province of Shaba (Zaïre).

On June 5, 1978, President Mobutu Sese Seko of Zaïre was invited to attend the third and unsuccessful test of the modular OTRAG rocket.



Launch sequence, on June 5, 1978, of the third test flight of an OTRAG modular rocket with 12 m long tanks and 4 clustered engines of 3 tons thrust. The vehicle, flew like a cruise missile, and was nicknamed V-3.

The OTRAG No. 3 rocket, launched June 5, 1978, failed to fly correctly to the sky, appearing as "a cruise missile jointly developed by Germany and Zaïre for a secret NATO project!"



The OTRAG launch team standing at the base of the typical standard module of the low-cost rocket. This OTRAG rocket No. 3 did not fly correctly on June 5, 1978.

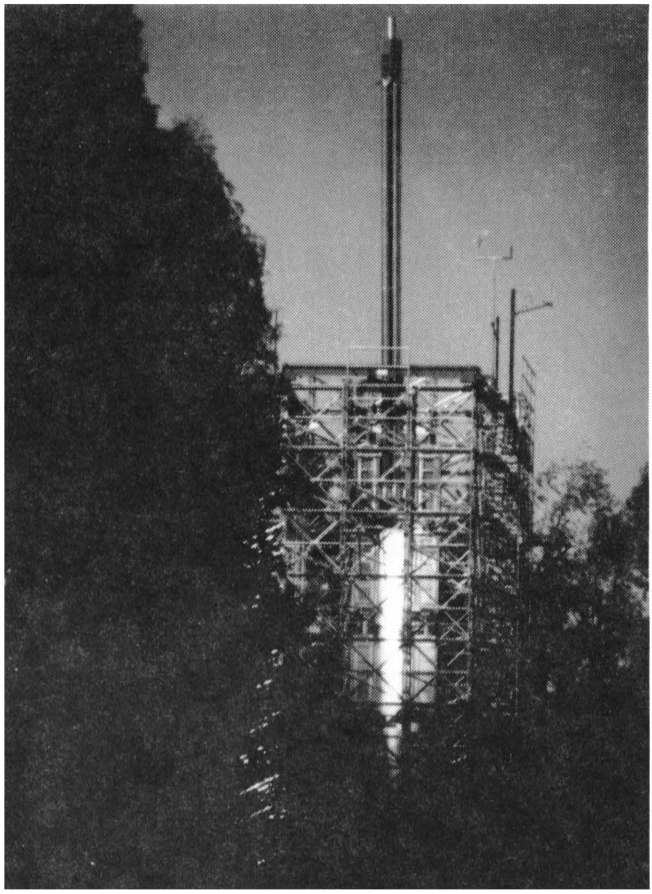
- OTRAG was the victim of the megalomania of its founder and president, Lutz T. Kayser. In order to convince the world about the commercial viability of "his" space rocketry venture, he announced the establishment of subsidiaries throughout the world: OTRAG France (with an office in Paris, on Foch Avenue), OTRAG Zaïre (with offices in Kinshasa and in Lubumbashi) and OTRAG USA (in project). [Note: Arianespace was preceded by OTRAG France!].

On June 28, Lutz T. Kayser held an international press conference at the prestigious Bayerisch Hof in Munich. He came with a chauffeur in a superb Rolls-Royce and he described with a movie the activities of OTRAG in Zaïre. He confirmed his contacts with other countries to open a second launch site. In November 1978, he tried—without success—to place OTRAG operations in Zaïre under the banner of the United Nations. During 1978, he demonstrated his personality as "a bit of a wheeler-dealer" (as depicted by Prof. Harry O. Ruppe, Director of the Department of Space Technology at the Technische Universität München) by getting money for OTRAG through the sale of the patents concerning the concept of modular rocketry. He would have obtained a first cash payment of 15 million DM or 10% of the total amount he requested.

- OTRAG, described by the media, especially in Germany, as a gigantic tax boondoggle, had to find new shareholders; its expenses continued to grow up dramatically, as shown in these financial data:

Status	Funding from shares	Total of investments
End of 1975	DM 27 million	DM 93.348 million
End of 1976	DM 55.58 million	DM 222.879 million
End of 1977	DM 75.98 million	DM 328.148 million

- OTRAG was working on the multi-stage concept for its clustered propulsion modules. It had to test it in a demonstration flight which was planned in 1979 with a 2-stage rocket. It was still far away from the first full-sized and largest OTRAG rocket, which would be able to launch a 10 t payload in LEO. It would consist of the clusters of 122 modules for the first stage, of 35 modules for the second, of 9 for the third stage, and of 3 for the fourth. A total of 169 modules or 676 engines/tanks, with a length of 24 m, would represent a launcher of some 1,000 tons!
  At the Technical University of Munich, engineers of the Department of Space Technology were skeptical about the official OTRAG goal to launch 10 t in LEO with the low-cost modular rocket system. Harry O. Ruppe, in October 1978, during the 29th IAF Congress at Dubrovnik, presented a technical paper about low-cost space transportation. This paper was negatively critical about the OTRAG project: insufficient launch acceleration, low specific impulse (232 s), nozzle thrust erosion, staging and inflight ignition, difficulties to control by differential thrust throttling, and critical vehicle reliability. The final conclusion was clear about the OTRAG concept: "from a cost standpoint, a private development, especially that on basis of 'low-cost propellants' with 'simplified high modular structure principle' does not represent a promising solution at all."



The astonishing and dramatic test launch of a rocket in Libya of the OTRAG rocket No. 4, March 1, 1981, from an oasis in the Sahara desert.

1979-1981: Change and Decline (the Libyan Connection)

OTRAG announced its aim to reach an altitude of 160 km with a single rocket consisting of one 12 m long module. A new demonstration was in preparation in early 1979. On April 26, 1979, under pressure from the Soviet Union, Angola and East Germany, Kinshasa authorities ended the launch site pact with OTRAG; President Mobutu asked OTRAG to close down the facilities and to stop activities in Shaba. Frank K. Wukasch, taking a leading role in the company, commented during a phone exchange: "With this unilateral decision of Zaïre, we lost 6 months to 1 year in our development program. We considered the possibility of launching our rockets from an ocean platform or from a 20,000 t ship but we had to abandon this too expensive idea. Finally, we got permission to install our transportable test facility in the Libyan desert without any rental charge or financial support." He admitted that, while Libya was not

directly concerned with the rocket testing, it showed a long-term interest in the use of communications satellites. However, the new OTRAG-Libya connection promised to be an explosive affair!

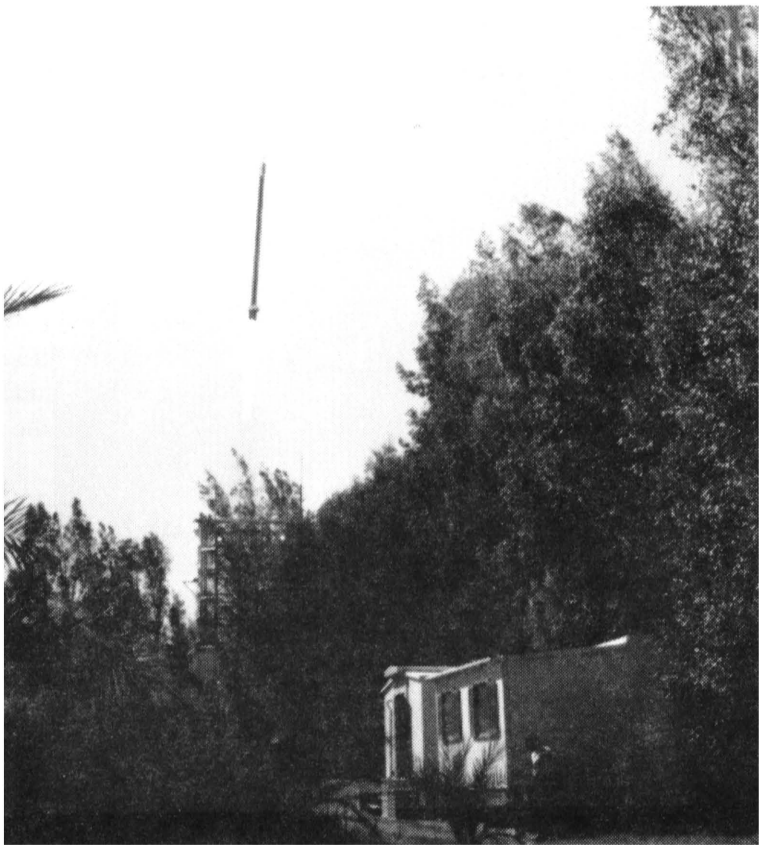
Other countries were approached by OTRAG for a launch site. The move to Libya was decided on by Lutz T. Kayser, because of the attractive conditions offered by Colonel Muammar Gaddafi. This choice frightened many shareholders of OTRAG, who asked for the dismissal of Kayser. Frank K. Wukasch took over the Presidency of OTRAG during 1980, replacing the founder of the company. Wukasch was still convinced that the modular concept was viable to develop a low-cost system for space transportation. Finding unacceptable and contradictory the technical data in the study of Prof. Harry O. Ruppe, he participated in the 31st IAF Congress at Tokyo in September 1980. He presented, with a 25-minute film, OTRAG launch vehicles: "The fundamental difference between the past, present and projected 'conventional' satellite launchers and those developed by our German company OTRAG is not only in the costs but in the philosophy of launcher construction."

His paper stated that OTRAG has spent an investment of more than 145 Million DM (from more than 1,400 German investors): "Total development costs are assuming that production will continue in West Germany and the launches will take place from a new launch site overseas and are estimated at about 660 million DM." An OTRAG document stated that the mass production of its modular rockets should require approximately 2,500 new employees of all grades, with some 18,000 people in a large number of subcontractors and subsuppliers! Frank Wukasch announced at Tokyo this revised calendar:

- concurrently with the preparation for a 2-stage launch in 1981, OTRAG would be able to offer launching services for high-altitude flights carrying scientific and technological payloads up to 400 kg up to altitudes between 250 and 300 km at the most competitive costs.
- in 1982, OTRAG would launch a 3-stage vehicle consisting of 48 clustered propulsion units which would carry an experimental payload.
- in 1984, OTRAG would offer launching services for 10 tons heavy payload into low earth orbit and 2 tons payload into geostationary orbit.

"A mass production and assembly of components of OTRAG launch vehicles is under preparation at the new-built facility at Garching near Munich. We are expecting to launch an average of 10 to 12 vehicles between 1984 and 1990. This includes all sizes of launch vehicles but most of them are expected to be in the larger category because the necessity of heavyweight payloads with large diameter will increase in the years to come." Wukasch also made this invitation: "OTRAG technology is suited in particular to the Third World countries because the production of most components of OTRAG launch vehicles can be

made locally. OTRAG relies on the use of existing national industry and on indigenous skills and talents of the local labor force."

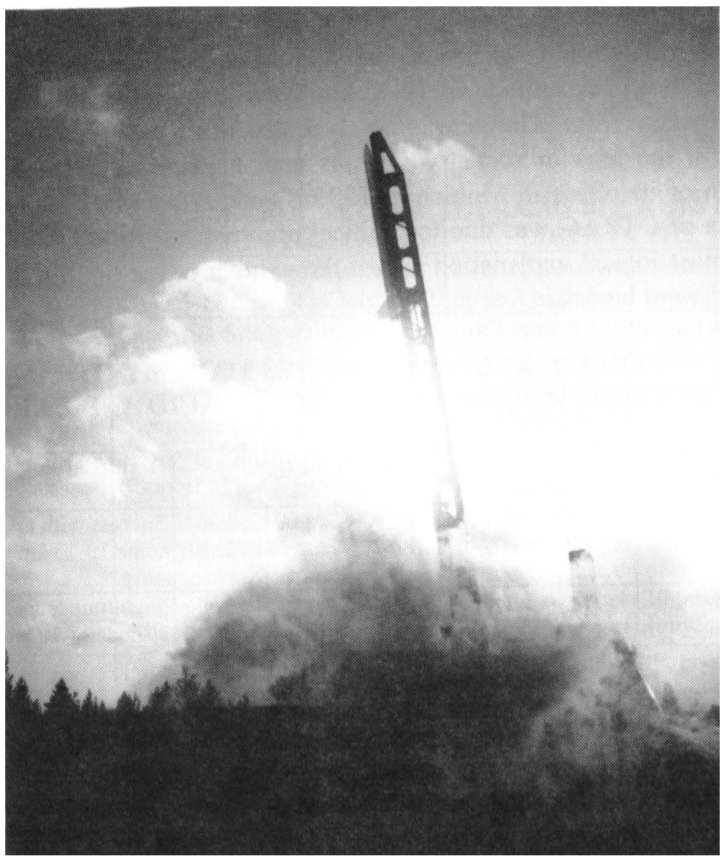


A "made in Germany" rocket in the sky of Libya. The OTRAG propulsion module No. 4, was tested on March 1, 1981, from an oasis in the Sahara desert.

The fact that Libya was the first of these Third World countries was really provocative. The Libyan test and launch site, decided on in 1980, was set up in seven months near Jarmash, some 700 km South of Tripoli, in the Sahara desert. It was 1 to 3 km^2 in size but featured thousands of km^2 of empty desert. Twelve German engineers and technicians, with the assistance of Libyan workers, participated in the establishment of the launch facility. On March 1, 1981, the fourth rocket of OTRAG was successfully launched from this facility. No precise result was given about this launch. For Frank Wukasch, Libya offered a provisional site and OTRAG had full autonomy in its operations.

At the end of 1981, OTRAG halted its Libyan activities. Fighting for the survival of OTRAG, Wukasch looked for new launch areas in the world, including an island in the Pacific Ocean, but outside Africa and the Middle East. However, rumors continued to circulate about the presence of OTRAG in many

Islamic countries. An NBC Television broadcast insisted on the military performances of the OTRAG rockets, and on contacts between OTRAG and Saudi Arabia for a missile deal. It was reported that Lutz Kayser was still helping Libya in the development of a missile. *The New York Times* associated the future of OTRAG with the development of "The Islamic Bomb" in Pakistan.



First operational - also called "commercial," but last "officially" OTRAG launch of a low-cost propulsion module. On September 12, 1983, and OTRAG sounding rocket became the first liquid launch vehicle fired from Esrange, in Kiruna, Sweden, to carry a German scientific payload at high altitude.

1982-1986: Low Profile and Termination (Return to Germany)

Diplomatically "killed" by its Islamic connection because of Libya, OTRAG was still in a hurry to demonstrate the efficiency of its modular system within its 10 years of existence, before the end of 1984. It stated it would achieve a propulsion-unit production of 5 per month in early 1983! Looking for the sounding rocket market, it marketed a family of modular vehicles. It tried in

Germany to get some governmental support and to convince scientific institutions to use its low-cost access to space. While OTRAG continued to plan the launch of a satellite in 1985-1986, the operational flight of a short propulsion module was prepared at Esrange-Kiruna, in Sweden. DFVLR (German Aerospace Research Establishment) contributed to this launch, for the countdown and control. MAN provided the mobile launch platform with mechanical and electrical connections. The payload of two scientific experiments, developed by teams from Munich and Aachen Universities was launched on September 19, 1983, to reach a peak altitude of 10-15 km. This first demonstration of the use of liquid rockets from Kiruna was not repeated. OTRAG became inactive in late 1984 in the area of rocketry systems and stopped its activities with the close-down of its office in Munich in 1986. Frank Wukasch explained that the termination of OTRAG was due to political pressure from the German authorities. The most logical explanation is that the company was definitively short of money and went bankrupt.

TABLE 2. KNOWN LAUNCHES MADE BY OTRAG PROPULSION MODULES USING NITRIC ACID AND KEROSENE

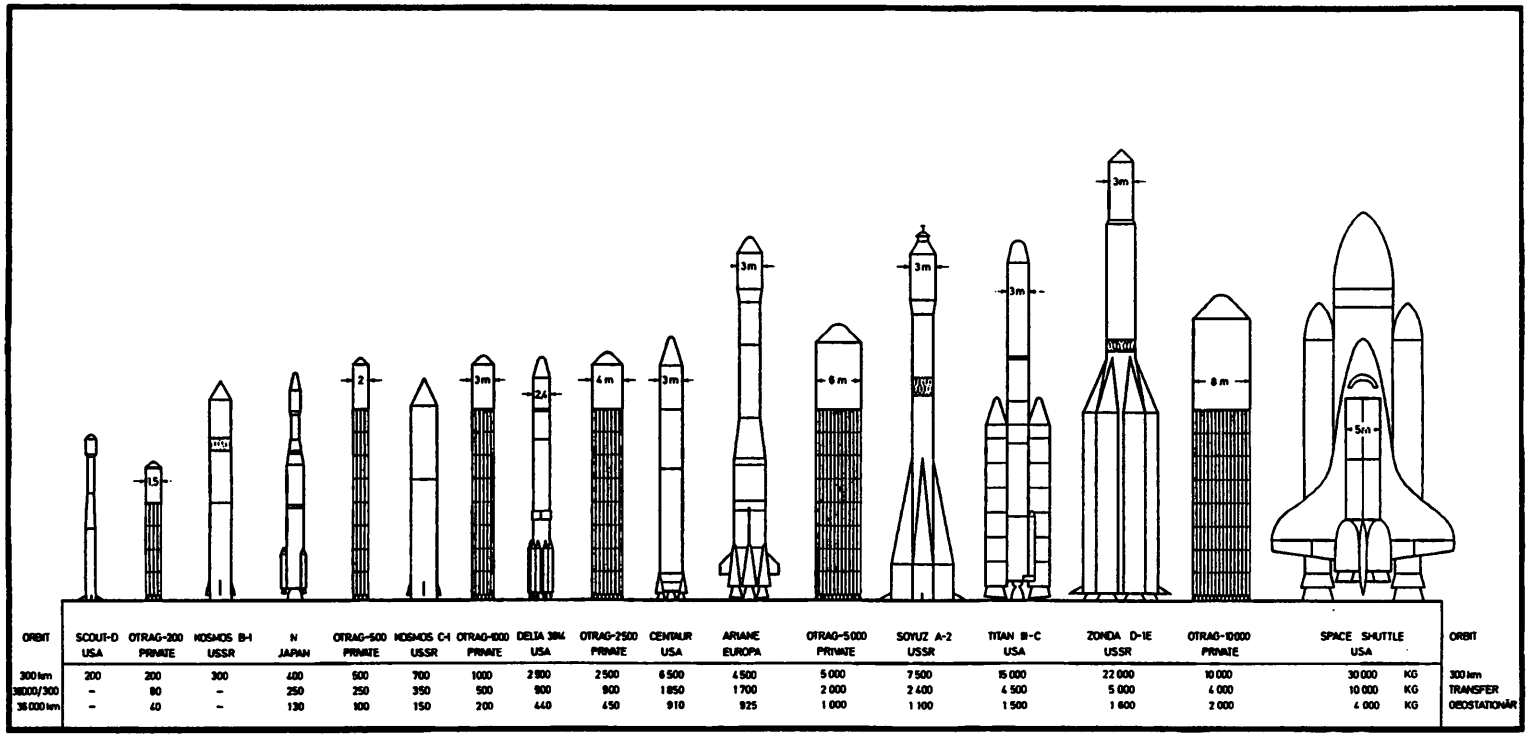
Launch date, local time (Launch site)	Configuration (Dimension	Target of the flight	Results of the launch
May 17, 1977, 10.15 (Shaba North, Zaire)	4 clustered tanks + engines /9 m high	Test of 4-engine module with 20 % fueled tanks; planned altitude: 20 km	Success with an altitude of some 10-15 km
May 20, 1978, 00.01 (Shaba North, Zaire)	4 clustered tanks + engines /9 m high	Test of the same type of module, with fully fueled tanks and with guidance system.	Nighttime launch, to reach an altitude of 30 km
June 5, 1978, 13.40 (Shaba North, Zaire)	4 clustered tanks /15 m high	Test of 12-m long propulsion module, with guidance system. Planned altitude: up to 100 km?	Malfunction of a control valve; rocket failing to reach its desired flight trajectory; launch attended by President Mobutu and international medias.
March 1st, 1981, 11.20 (Jarmah, Lybian Sahara)	4 clustered tanks /15 m high	Test of a new passive guidance system; 0.5 t of payload?	Successful launch but to which altitude? (up to 80 km?)
September 8, 1983, 7.59 (Esrange-Kiruna, Sweden)	4 clustered tanks /9 m high	First operational use, from a mobile platform, to carry a scientific payload of Munich and Aachen Universities for German DFVLR	First launch of a liquid sounding rocket from Kiruna; problems with payload recovery; no precise data about performances (altitude?)

Now the OTRAG venture is part of that History of Astronautics, which involves the dreamy and enthusiastic pioneers associated with the risky development of a privately offered free access to space: the Percheron of Gary Hudson (1981), the Dolphin of Starstruck (1984), the Conestoga of Space Services

(1982), and the Pegasus of Orbital Sciences Corporation. In spite of its non-efficient technology and Peenemünder reputation, OTRAG has definitively paved the way for worldwide business in space transportation services; Ariane- space was established by the French government on March 26, 1980, as a commercial venture for satellite launch operations throughout the world. In addition, OTRAG represented the first concrete step of space technology in the developing countries of the Third World.

TABLE 3 SUMMARIZING THE PRESENCE AND IMPACT OF GERMAN ROCKETRY IN THE AFRICAN COUNTRIES

FACTS	GERMAN ROCKETS IN EGYPT IN THE 1960's	GERMAN ROCKETS IN ZAIRE-LIBYA IN THE 1970's
Achievements	Limited number of launches: some 6-12 tests, 4 in July 1962	Limited number of launches: up to 3 in Zaïre, 1 or more? in Libya
Historical connection	Link with Stuttgart and Munich Aerospace Institutes, with some "Peenemunder" specialists (Eugen Sänger, Wolgang Pilz) as Professors	Involvement of Stuttgart and Munich Universities, with young enthusiast engineers, who were students of "Peenemunder" experts (Eugen Sänger, Wolfgang Pilz)
Mediatic impact	Support of the Egyptian medias to explain the prestige of Egypt in space research; great secrecy surrounding the development of the Egyptian missiles	Support of specialized medias to describe the original services with modular rockets for low-cost access to space; reaction of political medias explaining the peril of military projects in Germany, Zaïre and Libya
Technological aspects	Poor guidance system; heavy structures, with pressurized tanks; low-cost propellants (kerosene, nitric acid); 2-stage version on the drawing board but not tested	Too great simplicity; poor guidance system; heavy pipelines with simplified engines; low-cost propellants (kerosene, nitric acid) under pressure; multi-stage versions on the drawing board and not tested
Political effects	Strong reaction from the intelligence services of Israel against the German presence in Egypt; pressure of USA on Germany to welcome back the German engineers	Pressure of USSR on the German government to stop the activities of private venture in rocketry systems; suspicious information about its connection with West-German, then with Islamic military projects
Long-term vision	Venture terminated because of pressures of Israel, USA and Germany; first attempt to develop liquid rockets in a Third World country	Venture halted by financial problems and by political pressures from USSR, USA and Germany. pioneering the business of low-cost services for space transportation



ORBIT	SCOUT-D USA	OTRAG-200 PRIVATE	KOSMOS B-1 USSR	N JAPAN	OTRAG-500 PRIVATE	KOSMOS C-1 USSR	OTRAG-1000 PRIVATE	DELTA 3914 USA	OTRAG-2500 PRIVATE	CENTAUR USA	ARIANE EUROPA	OTRAG-5000 PRIVATE	SOYUZ A-2 USSR	TITAN III-C USA	ZONDA D-1E USSR	OTRAG-10000 PRIVATE	SPACE SHUTTLE USA		ORBIT
300 km	200	200	300	400	500	700	1000	2800	2500	6500	4500	5000	7500	15000	22000	10000	30000	KG	300 km
36000/300	-	80	-	250	250	350	500	900	900	1850	1700	2000	2400	4500	5000	4000	10000	KG	TRANSFER
36000 km	-	40	-	130	100	150	200	440	450	910	925	1000	1100	1500	1800	2000	4000	KG	GEOSTATIONÄR

References

Main Sources for Egyptian Rocketry and Space Activities:

[1]Jacques Villain, "France and the Peenemünde Legacy," in *History of Rocketry and Astronautics*, Vol. 21, *AAS History Series*, 1997, pp. 119-161 (paper IAA-92-0186, originally presented at the 43rd IAF Congress, Washington D.C., 1992).

[2]Alain Souchier & Patrick Baudry, *Ariane, L'Odyssée-Flammarion*, Paris, 1986, pp. 13-18.

[3]*Aviation Week & Space Technology*, September 9, 1963, pp. 32-33 and July 6, 1964.

[4]Correspondence from Dr. John W. Taylor, former editor of *Jane's 1966-67* and from Ken Gatland, former editor-in-chief of BIS *Spaceflight*.

[5]Correspondence with Dr. Hartmut Sänger (Terrassenstrasse, 2-4, D-76327 Pfinztal).

[6]Willy Ley, *Rockets, Missiles and Men in Space*, Signet Book, June 1969, pp. 552-554.

[7]Michel Bar-Zohar, *La chasse aux savants allemands, Editions Arthème Fayard, 1965*. Chapter: "Nasser embauche des Allemands," pp. 243-269 (particular thanks to Hervé Moulin for the copy of these interesting pages).

[8]Susanne Pach, "Rolf Engel," in *Spaceflight*, Vol. 22, 6 June 1980, pp. 231-236.

[9]Correspondence with John Pitfield, Rocket Systems, who transmitted a lot of useful press clippings about Egyptian rockets of the 1960s.

Main sources for the OTRAG Venture:

[1]*Hobby, Das Magazin der Technik*: Deutschland revolutioniert den Raketenbrau, 14 August 1974, pp. 12- 18; *Der Weltraum-Spediteur*, 10 August 1977, pp. 48-53.

[2]Brochures & information released by OTRAG, between 1977 and 1983; correspondence and phone exchanges with Frank K. Wukasch (Königsbergerstrasse, 2, D-85748 Garching/München).

[3]*Afrique-Asie*: Mobutu vend un dixième du Zaïre pour des fusées allemandes, 8 August 1977, pp. 26-30.

[4]Robert R. Ropelewski, "Low-cost satellite launcher developed," *Aviation Week & Space Technology*, September 12, 1977; Eugene Kozicharow, "OTRAG locates rocket testing on Libyan site," *Aviation Week & Space Technology*, December 1, 1980, pp. 18-20.

[5]Theo Pirard, "German Company Blasts into Space Age," *L5 News*, October 1977, pp. 6-7, Jim Oberg, "Private enterprise in space - The rise, fall, and rise of OTRAG," *L5 News*, December 1980, pp. 8-11.

[6]*Africa Magazine*: "Space Technology and Africa," December 1977, pp. 49-57.

[7]Kenneth W. Gatland, "Into space by low technology," *Spaceflight*, January 1978, pp. 2-8.

[8]Tad Szulc, "In the heart of Africa... V-3, an investigation of Tad Szulc," *Penthouse*, March 1978, pp. 19-22.

[9]"Bargain-basement rocket," *Popular Science*, March 1978.

[10]"Volksraketen for the Third World," *New Scientist*, 23 March 1978, pp. 802-803.

[11]Robert Poole, Jr., "Rockets in Africa," *Reason Magazine*, July 1978, pp. 16-23; James C. Bennett, "Getting off the Ground, *Reason Magazine*, November 1981, pp. 21-31.

[12]"Deutsche Raketen in Afrika," *Der Spiegel*, 14 August 1978, pp. 52-65.

[13]Harry O. Ruppe, IAF-78/A26, "Low-cost space transportation," 29th IAF Congress, Dubrovnik, October 1978.

[14]Dr. Frank K. Wukasch, IAF-Tokyo, "Low-cost transportation systems of the 80's: OTRAG Launch Vehicles," 31st IAF Congress, Tokyo, September 1980.

[15]Transatlantik: Das OTRAG Dossier, October 1980, pp. 44-55.

[16]"Auch so kann man Raketen bauen," *PM Magazine*, 12 June 1981, pp. 12-18 (with a lot of drawings).

[17]"NBC Magazine with David Brinkley," (transcript), June 18, 1981.

[18]Jeffrey M. Lenorowitz, "OTRAG to market sounding rockets" and "OTRAG prepares for full launch services," *Aviation Week & Space Technology*, on October 4, 1982 and September 12, 1983.